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ON THE CONNECTION BETWEEN THE ELECTRICAL AND ELASTIC PROPERTIES OF SEDIMENTARY ROCKS OF SOUTHERN EMBA AND MANGYSHLAK

A. B. Li and A. N. Danilin

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ON THE CONNECTION BETWEEN THE ELECTRICAL AND ELASTIC PROPERTIES OF SEDIMENTARY ROCKS OF SOUTHERN EMBA AND MANGYSHLAK

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In recent years in the area of Mangyshalak and southern Emba in connection /73* with their oil and gas resources, a large number of deep holes have been bored and comprehensive industrial-geophysical research carried on. Industrial-geophysical research, and in particular electrocoring, has produced extensive material for studying the physical and collector properties of rocks comprising the geophysical cross-sections and for separating tapering zones of collectors and their facies variability.

Establishing a relationship between electrical and elastic properties of rocks makes it possible to construct a velocity profile using electrocoring materials. Consequently, one is not limited to constructing velocity profiles from a small amount of seismocoring material (usually one or two boreholes in an area). The favorable solution of this problem contributes greatly to the interpretation of seismological prospecting data.

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*Numbers in the margin indicate pagination in the original foreign text.

The assumption that a connection exists between the electric and elastic properties of rocks is based on the fact that both are connected with density and porosity .

The basic factors determining electrical conductivity in sedimentary rocks are porosity and mineralization of stratified water in the absence of minerals with electron conductivity in the rock. Such a condition has been maintained in the regions under consideration. The relation of electrical conductivity of rocks to their porosity has the form

$$\rho_r = f(K_p) \cdot \rho_w$$

where ρ_r — specific electric resistance of the rock;
ρ_w — specific electric resistance of the stratified water;
$f(K_p)$ — some function of porosity.

Now a technique has been developed to convert apparent specific electrical resistance (KS) measured in the bore to actual specific electrical resistance of the layers (ρ_w). As a result of side coring probing (BKZ) [1] in /74
the majority of cases the specific electric resistance is successfully determined for individual "homogeneous" layers, i.e., freed from various distorting influences (neighboring layers, influence of the bore, etc.).

For physico-lithologic characteristics of rock, the value ρ_r is more important than the value of apparent specific resistance. In practice, we encounter layers only approximately homogeneous. Therefore, the value ρ_r is to some measure an average characteristic of the layer.

In comparing strata characteristics, it is advisable to convert from specific resistance to relative resistance $P_r = \frac{\rho_r}{\rho_w}$ of the layer, which shows how many times greater the specific resistance of the rock is than the specific resistance of the stratified water. It also establishes the basic lithological structure of the rock.

Under laboratory conditions, electric resistance was measured in samples of sedimentary rock such as sandstone, clay, and argillite. The pores of these rocks were filled with a saturated solution of sodium chloride.

The only elastic property of the rocks determined by the laboratory method was the propagation rate of longitudinal elastic waves which was measured by a US-2 seismoscope. As is known, the velocity of elastic longitudinal waves in sedimentary deposits is also determined by structure and physical properties of rock phases and their skeleton.

In determining the velocity of elastic longitudinal waves under laboratory conditions, the samples met certain specifications: they were homogeneous in composition and had fixed dimensions (length, diameter).

Experiments conducted on artificially prepared rock samples showed that to obtain velocities, measured by the laboratory method and close to natural propagation rates of longitudinal elastic waves, samples with the following dimensions are necessary:

Length of sample, mm	Diameter of sample, mm	Difference between velocities in natural beds and in laboratory conditions, %
90	115	none
150	83	1
150	54	2
150	47	6
150	40	10

In determining the propagation rates of longitudinal elastic waves, it was usually necessary to use samples from 30 to 100 mm in length and 40 to 54 mm in diameter. Therefore, to reduce propagation rates of elastic longitudinal waves obtained by laboratory methods to the propagation rate of elastic longitudinal waves in the natural rock beds it is necessary to use master curves of correction factor μ to calculate the effect of the volume of the sample on the propagation rate of elastic longitudinal waves due to their diffraction (Figure 1). The master curves are plotted according to experimental laboratory data on artificially prepared samples.

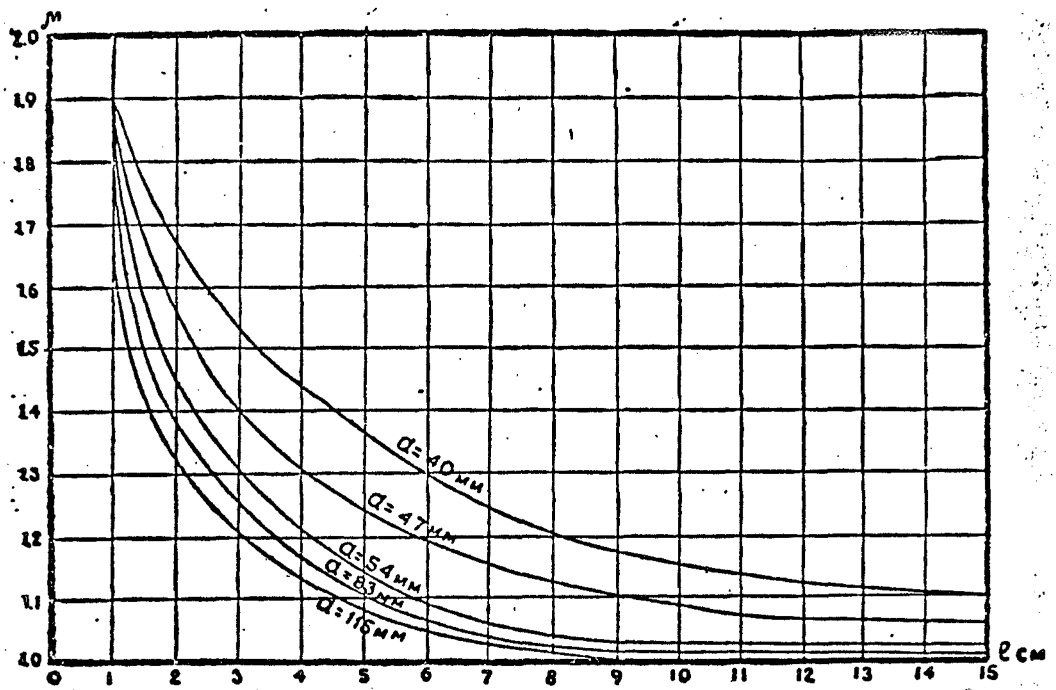

Figure 1. Master curves of correction factor μ for computing the effect of a finite volume of a sample on the propagation rate of longitudinal elastic waves.

After the accumulation of a large volume of laboratory determinations of relative electric resistance and propagation rates of elastic longitudinal waves (more than 500 samples of various areas) their relation was plotted (Figure 2). The relation obtained is analytically expressed by the function $P_r = 1.48 \cdot e^{0.00132 \cdot \nu}$. Using this relation, it is possible according to electrocoring materials to plot a seisom-geological profile which, without doubt, is of great interest.

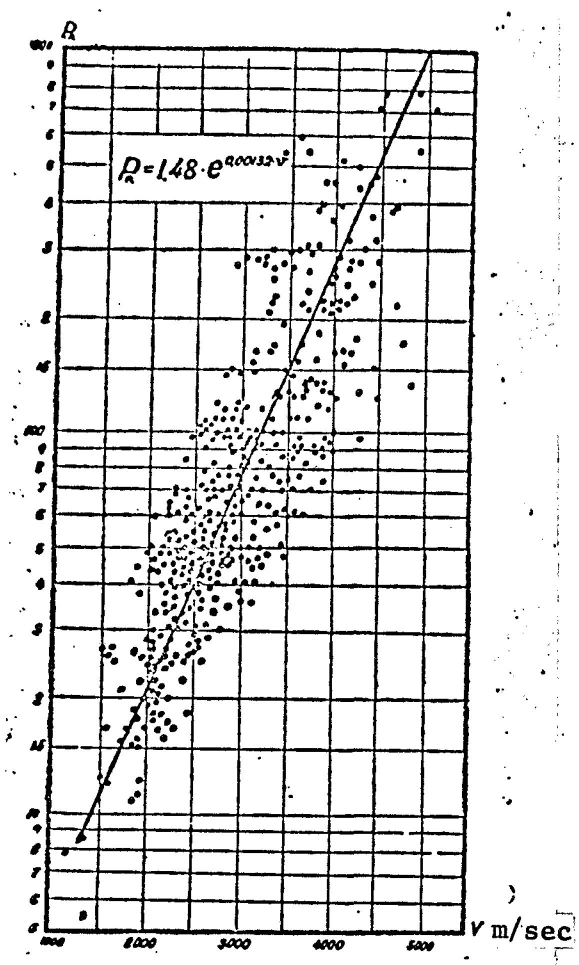

Figure 2. Dependence of relative electric resistance (P_r) on the propagation rate of longitudinal elastic waves (v) for the sand-clay profile of Southern Emba and Mangyshlak.

<u>Plotting Average Rate Curves from the Interior and Layer Velocity Curves According to Results of Electrometric Research in Boreholes</u>

Using industrial-geophysical research in boreholes (side boring probing, cavity measuring, measuring natural potential of PS rocks), homogeneous layers were distinguished. To determine specific electric resistance of the layers, master curves of the All-Union Scientific Research Institute of Geophysics were used: L. M. Al'pin, EKZT; salinity of the stratified water was determined according to the technique of A. M. Nechaka [2]. Using the dependence of /75 the relative electric resistance on the propagation rate of elastic longitudinal waves, we find rates for strata whose relative electric resistance is determined by the means noted above.

In considering this question, we are concerned with the average propagation rate of elastic longitudinal waves, which is expressed as $v = \frac{\Sigma v_i \cdot h_i}{\Sigma h_i}$, and serves as an approximate expression of the law governing average rates from the interior.

Layer velocities of elastic waves are determined for strata isolated by electrocoring diagrams whose propagation rate of longitudinal elastic waves is different. In this case, each layer has its own relative electrical resistance. According to this value (Figure 2), we find the layer velocity.

To prove the reliability of determining average and layer velocities of elastic longitudinal waves with the use of electrocoring and the function $p_r = f(v)$, obtained under laboratory conditions, for two bores in the areas of Burankul' (bore 2) and Makat (bore 3) we give results of seismocoring (Figures 3,2,c and 4,a,c).

In computing the velocities of elastic longitudinal waves using electrocoring and function $P_r = f(\nu)$, it was assumed that all pores in the rocks were filled with a saturated solution of sodium chloride (mineralization of stratified water 230 - 250 g/l). Figures 3,a and 4,a give curves showing change in average rates from the interior, plotted according to seismocoring and using electrocoring. The difference in determining average propagation rates of elastic waves from the interior is less than 100 m/sec. This difference can be explained:

(1) by the different technique of working with seismo- and electrocoring;

(2) by the effect of drilling fluid and the diameter of the bore in seismocoring;

(3) by the effect of temperature and pressure in the bore under the operating conditions of seismic detectors (at depths beyond 2000 m, the temperature is over 100° and the pressure about 300 atm);

(4) by inaccuracy of determining the specific resistance of stratified water by electrocoring.

Layer velocities obtained by the calculation method compare well with layer velocities determined by seismocoring.

Analysis of calculated layer velocities makes it possible to distinguish a large number of reflecting layers (base of tertiary deposits — 1st reflecting layer, base of Aptian-upper part of Barremian — 2nd reflecting layer, /76

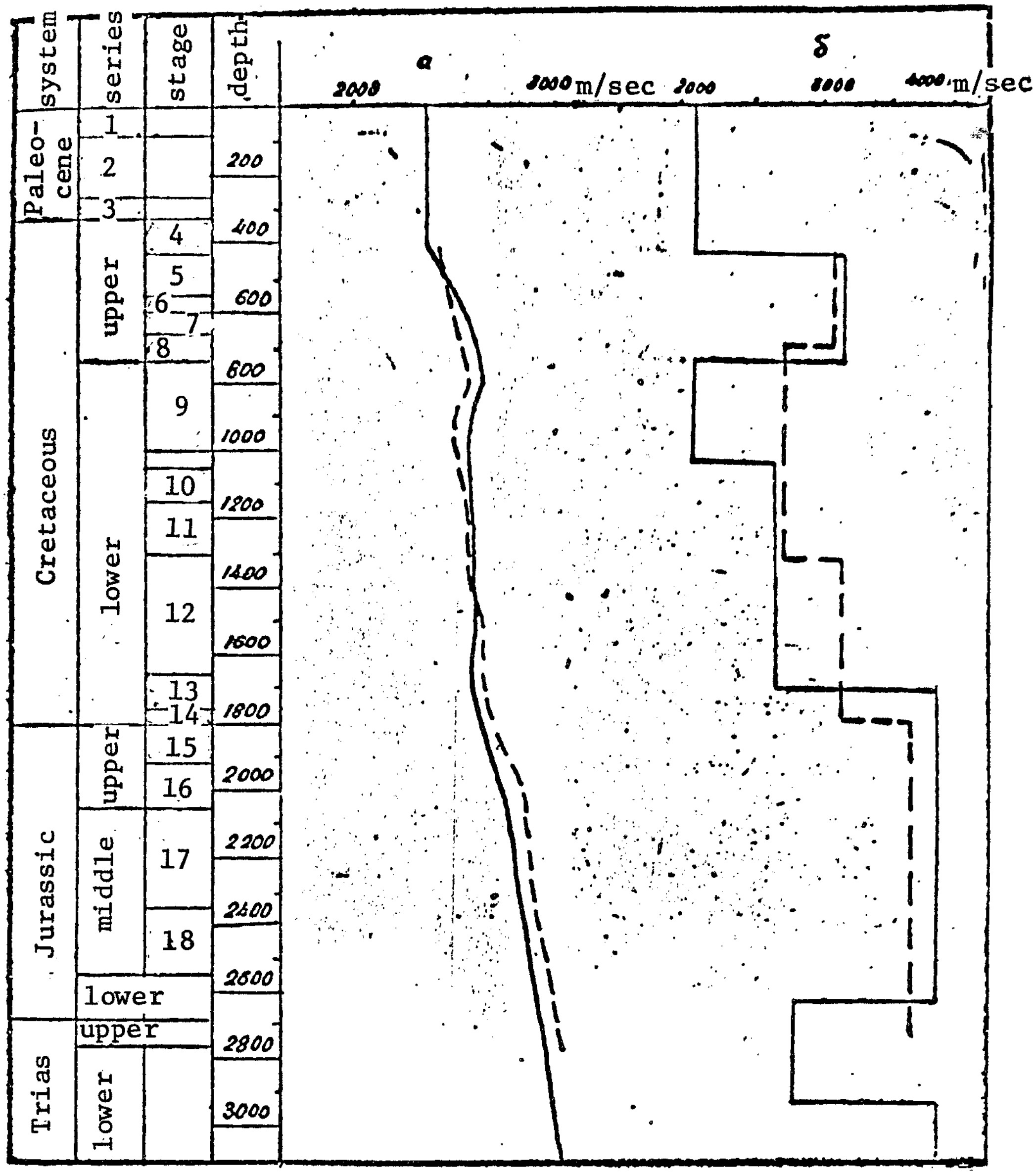

Figure 3. (a) _____ curve showing change in average propagation rates of longitudinal elastic waves from the in erior obtained with the use of electrocoring materials (Burankul', bore 2).

----- curve showing change in average propagation rates of longitudinal elastic waves obtained by seismoboring data (Burankul', bore 2).

(b) ——— curve showing change in average layer velocities obtained with the use of electroboring materials (Burankul', bore 2).

----- curve showing change in average layer velocities, obtained by seismoboring data (Burankul', bore 2).

1 - Oligocene lower; 2 - Eocene upper; 3 - lower; 4 - Maestrichtian; 5 - Campanian; 6 - Santonian; 7 - Turonian; 8 - Cenomanian; 9 - Albian upper 10 - Albian lower; 11 - Aptian; 12 - Neocomian; 13 - Hauterivian; 14 - Valanginian; 15 - lower Volga; 16 - Callovian; 17 - Bathonian; 18 - Bajocian.

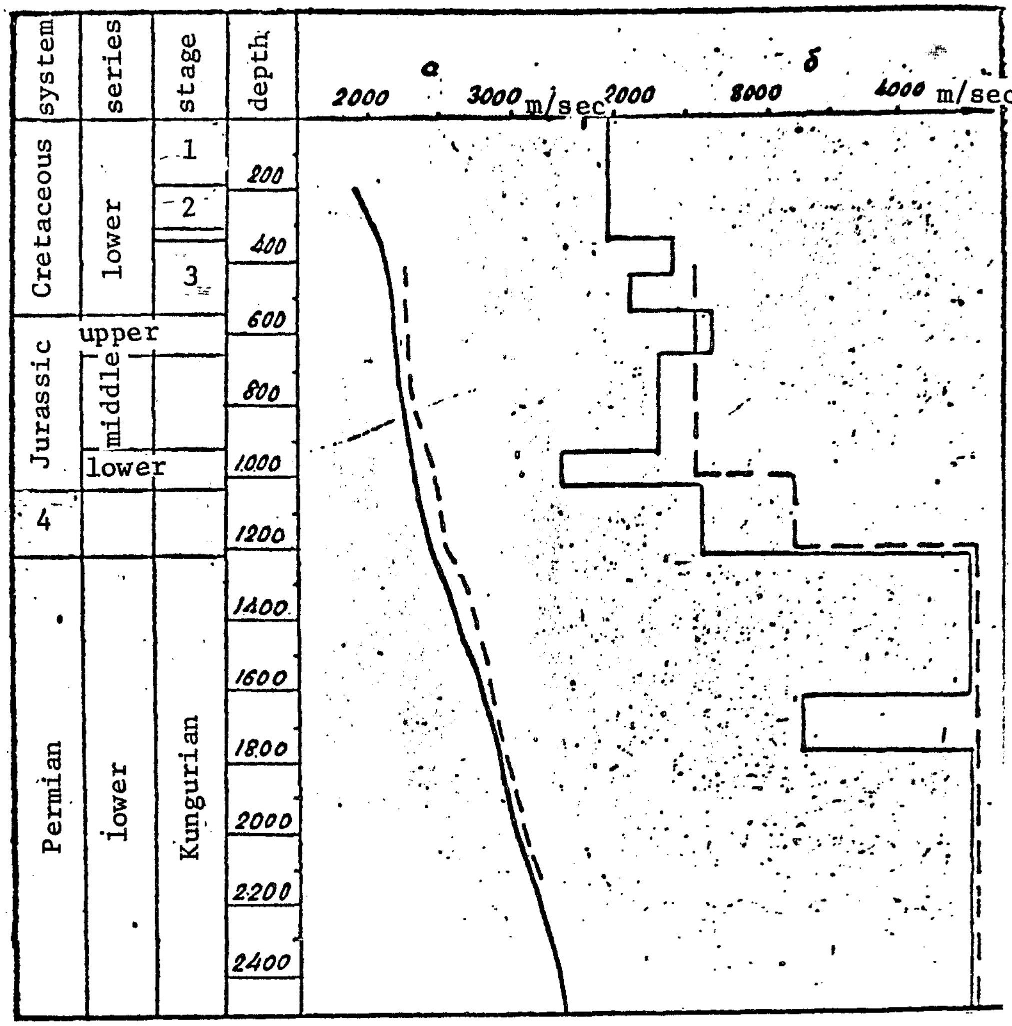

Figure 4. (a) ——— curve showing change in average propagation rates of longitudinal elastic waves from the interior obtained with the use of electrocoring materials (Makat, bore 3).

----- curve showing change in average propagation rates of longitudinal elastic waves obtained by seismocoring data (Makat, bore 3).

(b) ——— curve showing change in average layer velocities obtained with the use of electrocoring materials (Makat, bore 2).

----- curve showing change in average layer velocities, obtained by seismocoring data (Makat, bore 3).

1 - Albian-cenomanian; 2 - Albian; 3 - Neocomian; 4 - Permo-Trias.

and also possible boundaries within Cretaceous and Jurassic deposits, correlated to the base of the Neocomian stage — 3rd reflecting layer, and to the base of the middle Jurassic — 4th reflecting layer.

In the profile of Paleozoic deposits, characteristic reflecting layers are the upper part of Permo-Triassic deposits — 5th reflecting layer and upper part of salt deposits — 6th reflecting layer.

Judging from the data obtained, seismic marker beds can be distinguished within the Kungurian stage — thick layers of salt, for example, covered with layers of clay rock (Figure 4,b, depths of 1615 - 1780 m).

Layer velocities obtained by using electrocoring make it possible to distinguish reflecting layers confidently and indicate the existence of secondary reflecting surfaces in a stratigraphic profile.

For detailed separation of the geological profile according to velocity properties, layer velocities were also determined for thin strata in borehole 5 in the Uzen' area (Figure 5, $h < 10$ m). It is evidently impossible to distinguish the number of layers according to seismocoring data with the existing procedures, because of the strong differentiation of the stratigraphic profile by velocity characteristics.

In other countries acoustic coring material is usually used for detailed evaluation of the velocity profile. But a large number of researchers — Kokesh, 1962; Blizard, 1962; Wood, 1962; and Hicks, 1962 — have established that the accuracy of the velocity profile determined by acoustical boring material decreases because of geometric factors — thickness of the layer, diameter of the borehole, the cavity, distance between detectors, and also changes in the rock in the part of the borehole near the face, due to the action of the drilling fluid (collector zone, shearing effect). All these factors influence the accuracy of determining true velocities, and therefore

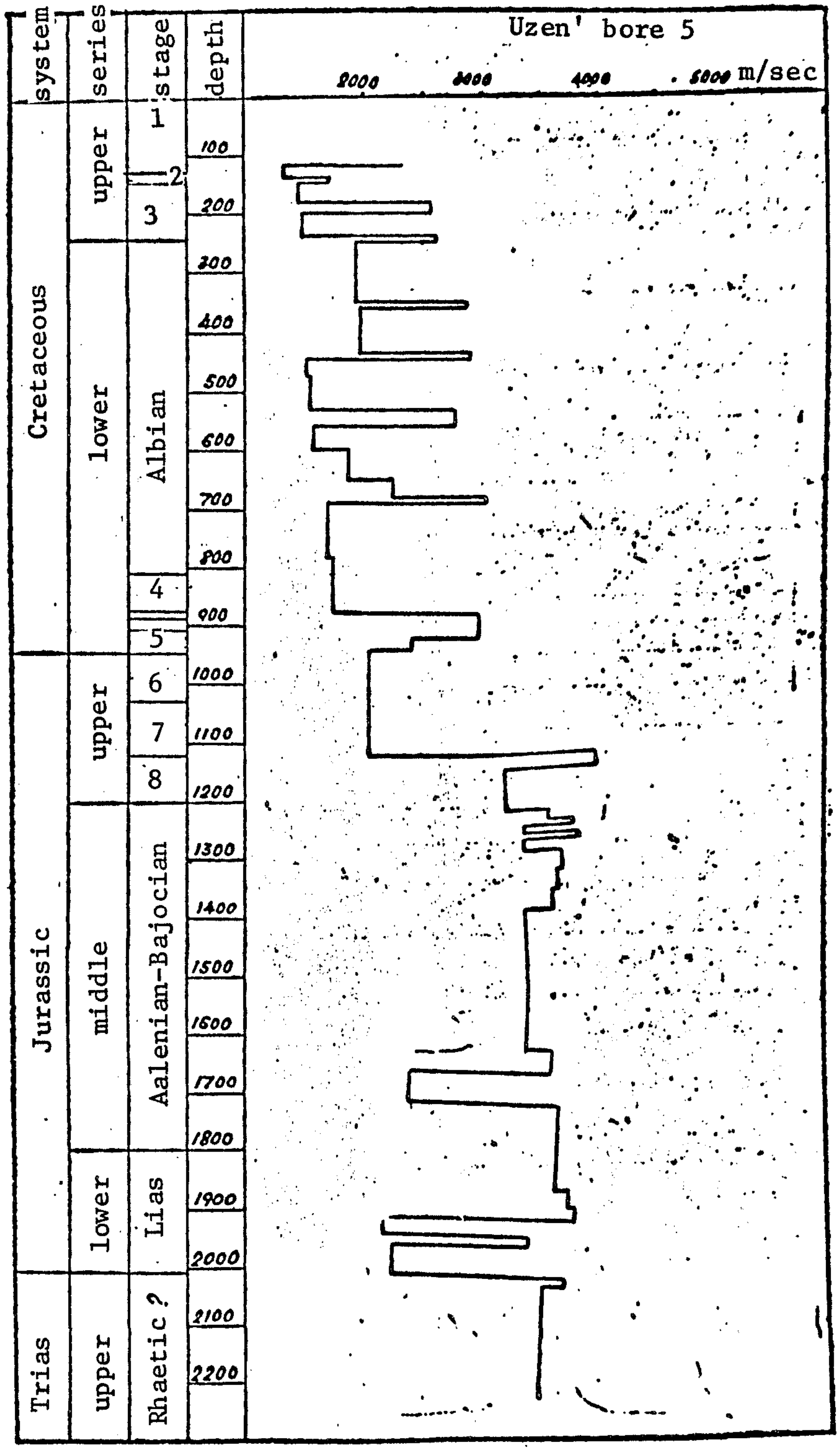

Figure 5. Velocity profile (V_e) plotted with the use of electrocoring data, allowing for thin layers — over 10 m (Uzen', bore 5). 1 - Campanian; 2 - Santonian; 3 - enomanian; 4 - Aptian; 5 - Valangian; 6 - Oxford; 7 - Callovian; 8 - Bathonian.

in tracing acoustical coring on diagrams approximate layer velocities are recorded. In view of the fact that until now a sufficiently complete theory of ultrasonic coring has not been developed, conversion from approximate to true velocities is quite difficult.

For electrical coring, the theory has been developed in detail and the conversion from approximate to true specific resistances does not cause any difficulty. Pickett, 1962, and Wood, 1962, on the basis of tests, indicate a sustained correlation between the propagation rate of elastic longitudinal waves and the specific resistance of rock. Therefore, using electrocoring materials to evaluate the velocity profile is relatively sound.

The possibility of detailed determination of the velocity structure of geologic profiles has been an impetus in the development of a new trend in analyzing seismic data — seismogram synthesis. This trend in recent years has been successfully developed in the USSR and in a number of foreign countries, especially in France and the USA [9].

Plotting synthetic seismograms amounts to distinguishing reflecting surfaces with the help of electrocoring. Relative resistance of each layer is pre-determined by electrocoring. The boundaries of the layers are segregated according to the regulations set for industrial-geophysical research [3]. /77

In view of the fact that the reflecting boundary develops when the acoustic rigidity changes on the boundary of two layers, graphs (Figures and 6) are used to find the acoustic rigidity ($\nu \cdot \sigma$). Figure 6 gives the relation of relative electric resistance to the density of the rock for sand-clay profile and porous limestones, plotted according to the results of laboratory tests.

Having determined acoustic rigidity and using standard formulae, we calculate the amplitude of reflecting waves which develop at each change of

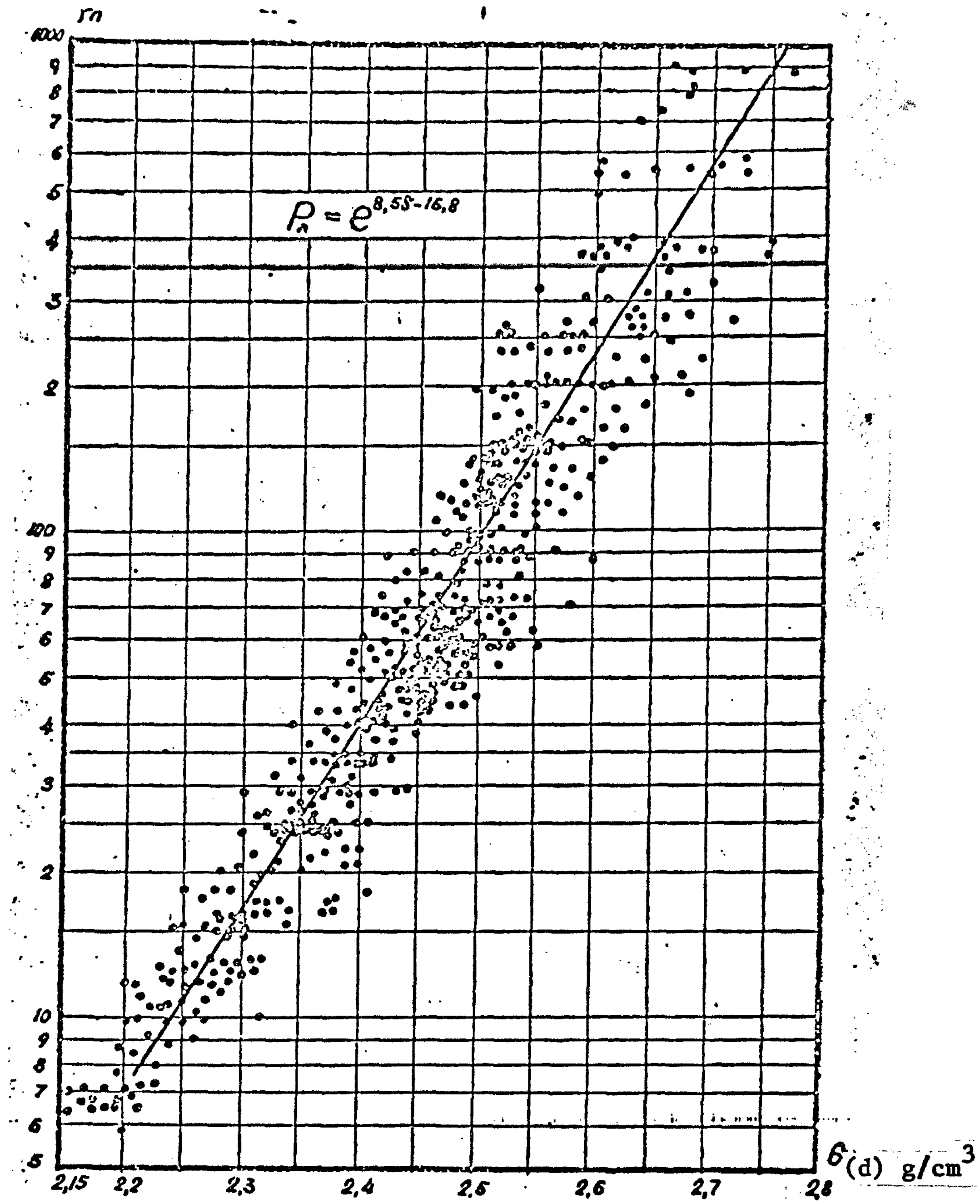

Figure 6. Relation of relative electric resistance (P_r) to density (σ_d) for sedimentary rocks of a sand-clay section of Southern Emba and Mangyshlak.

acoustic rigidity.

To obtain reflected impulses in true time relation, the depth scale is changed to correspond to the time scale of the double trajectory.

When the geological profile is composed of an insignificant number of layers with constant acoustic rigidity, then plotting synthetic seismograms is not complicated. Actually geological profiles include a large number of layers. Therefore, it is necessary to consider the large number of boundaries of sections and to plot automatically synthetic seismograms.

The use of synthetic seismograms can solve the following problems:

(1) evaluate the prospecting potentialities of a reflected wave system /80 in studied territories and select the optimum observation technique for tracing reference reflections;

(2) clarify factors which make it difficult to distinguish reflections and develop effective means to remove them;

(3) evaluate the role of various multiple waves and find criteria for distinguishing single reflections in field recordings;

(4) tie reflecting layers together stratigraphically and clarify dynamic criteria for correlating reference reflections by area.

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